MEMORY FUNCTIONS IN TEMPORAL LOBE EPILEPTICS: COMPARISON BETWEEN GROUPS WITH RIGHT AND LEFT UNILATERAL FOCI

By

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The fact of memory disturbance in temporal lobe epileptics has long been noted. While research has established that right and left temporal areas subserve, generally, nonverbal and verbal memory functions respectively, few data are available from studies using groups of highly discriminated right and left temporal lobe epileptics free from bilateral dysfunction or any form of gross cerebral dysfunction. In addition, memory measures labeled as verbal or nonverbal have not been established as conclusively valid.

The present study addressed these issues by utilizing a population of fourteen right temporal lobe epileptic cases and fourteen left temporal lobe epileptic cases all extensively established as free from bilateral involvement or gross cerebral dysfunction, to whom were administered a number of verbal and nonverbal memory measures, as well as a measure of general intelligence. The groups were well-matched in terms of age,

education, and general intelligence. It was hypothesized that left temporal subjects would perform more efficiently on nonverbal measures, that right temporal subjects would perform more efficiently on verbal measures, that right temporal subjects would perform significantly better on a facial recognition task (contrary to its usage as a nonverbal task), and that left temporal subjects would perform significantly better on a visual reproduction (supposedly nonverbal) task.

The data were subjected to a stepwise discriminant analysis program which accurately classified 79% of the cases into their respective groups. All of the mean scores were in the predicted direction and, when combined, generated positive F values, accurately predicting right vs. left cases. These results were taken as providing qualified support for the first two hypotheses, qualified in the sense that not all of the verbal and nonverbal measures added significant predictive value to the discrimination of right vs. left cases. The last two hypotheses failed to receive support, although the scores were in the predicted direction.

It was concluded that a series of verbal and nonverbal memory measures could adequately distinguish right vs. left temporal lobe epileptic cases, even when all subjects were highly functional, displaying only subtle differences in performance. Ways to enhance the predictive value of a series of memory measures were discussed.

Chapter I

INTRODUCTION AND HISTORY

Introduction

The long history of epilepsy as a clinical entity began in the fourth century B.C. with Hippocrates (Penfield and Jasper, 1954) who, in his description, spoke of memory disruption as a frequent accompanying symptom. Later both Seneca and Galen, among others, characterized epileptics as experiencing severe memory difficulties (Temkin, 1945). Through the centuries, descriptions of epileptics and epilepsy have continued to make prominent mention of associated memory problems. Several turn-of-the-century writers (Gowers, 1881; Lombroso, 1891; Turner, 1907), following reviews of the historical literature, reported memory disruption as a most frequent symptom of epilepsy and perhaps the only one available in its slighter forms. Interest in the ways in which epilepsy affects memory function has continued and progressed beyond the simple description of its presence. Modern researchers address a number of more molecular issues under the broader rubric of memory function in epilepsy.

The present study was concerned with the relative efficiency of memory functions between epileptic patients identified as suffering from seizure activity localized to the temporal lobe of one hemisphere and those suffering similar activity in a corresponding area of the opposite hemisphere. In undertaking this particular area of study, an issue was approached which has received a substantial amount of tangential, but little direct, attention.

Review of the Literature

Issues in Localization

While impairment of memory due to focal lesions of the brain has aroused increasing interest among researchers, especially over the last two decades, there have been dissenting voices. Kolodny (1929), after a series of studies using patients with frontal and temporal lesions, decided that memory is much more a function of the brain as a whole than of any specific area. MacKay (1955) stated that the attempt to localize memory in any part of the nervous system is futile. These views have been swamped by a rising tide of studies (E. G. DeJong, 1973; Drachman and Arvit, 1966; Milner, 1970; Penfield and Milner, 1958; Samuels, Butters, and Fedio, 1972; Scoville, 1954; Scoville and Milner, 1957) which have shown the importance of the temporal lobes and especially their medial structures (the uncus, the hippocampus, the hippocampal gyrus) for human memory function. Damage to these structures may result in severe and frequently permanent disturbance of recent memory while leaving more established memories, professional skills, and general intellectual functioning largely intact (Stepien and Sierpinski, 1960). While the role of the temporal lobes in memory function is now generally accepted (Serafetinides, 1969), there is less agreement over whether bilateral damage to temporal areas is necessary for memory loss to occur, or whether damage confined to one lobe is sufficient. Some authors (Drachman and Arvit, 1966; Scoville, 1954; Victor, 1964) have argued that both lobes must be involved if memory defect is to be manifested. DeJong (1973), after reviewing pertinent studies, decided that it is most unusual to find a case of memory defect occurring with a unilateral lesion without some evidence of damage in the contralateral lobe.

Dimsdale, Logue, and Piercy (1963), however, have reported cases of memory loss with unilateral damage when no contralateral damage was detectable, as have Serafetinides and Falconer (1962). Fedio and Mirsky (1969) have taken the more moderate view that the degree of memory loss, and not its presence or absence *per se* is affected by whether the damage is bilateral or unilateral. This formulation was given support by Milner (1970) who pointed out that although unilateral temporal lesions may result in far milder defects, they nevertheless fall within the domain of memory. Other researchers (De Renzi and Faglioni, 1965; McFie and Piercy, 1952) have suggested that perhaps the crucial variable in memory disruption is the extent or severity of the damage in relevant areas, whether bilateral or unilateral; however, at least one study (Blakemore, Ettlinger, and Falconer, 1966) concludes that cognitive disabilities are not significantly related to the severity of temporal lobe epileptic lesions. Some researchers (Blakemore et al., 1966; Lansdell, 1962; Mirsky, Primac, Marsan, Rosvold, and Stevens, 1960) have suggested that the memory dysfunction associated with temporal lobe epileptogenic foci may not be manifested unless the disorder has been present for some time, possibly in excess of 10 years (Mirsky et al., 1960). This particular view has apparently generated little interest, and is seemingly of secondary importance to the presence or absence *per se* of the memory disorder. While the question of localization has yet to be fully resolved, there is sufficient evidence to suggest that a unilateral temporal focus may result in varying degrees of memory disruption.

Lateralization of Function

For many years man was considered to have a "twin brain" with the two hemispheres anatomic and functional equals (Smith, 1966); however,

since the early 1950's much active investigation in human perceptional asymmetry has taken place, establishing that the two hemispheres subserve different functions. This research has important implications for the study of memory as a multifaceted process which encompasses the retention and recall of varying materials; e.g., verbal, visual, auditory, mediated through various senses; e.g., vision, hearing, tactile.

While studying populations of patients who had undergone unilateral temporal lobectomy to relieve epilepsy, researchers found that when the effects on memory of left and right temporal lobectomies were compared, the most significant variable to emerge is whether the material to be retained is verbal or nonverbal (Milner, 1958, 1970; Kimura, 1963; Reitan, 1955; Samuels et al., 1972). Left temporal lobectomy (in the dominant hemisphere for speech) selectively impairs retention of verbal material whether the material to be retained is heard or read (Blakemore and Falconer, 1962; Milner, 1967). This appears to be the case regardless of how retention is tested (Milner, 1958; Milner and Teuber, 1968). Removal of tissue from right temporal areas leaves verbal memory intact, but interferes with recognition and recall of certain visual and auditory material (Kimura, 1963; Milner, 1968). Other studies have found similar results using as subjects patients who suffered right or left temporal damage as determined by E.E.G., neurological examination, neuroradiological data, etc. Thus De Renzi (1968) concluded that the left hemisphere plays a major role whenever the retention of test material can be aided by verbal identification, and the right hemisphere when one must rely entirely upon perceptual clues. Fedio and Mirsky (1969) found similar results using children with temporal lobe disorders. Those children with left temporal lobe epileptic involvement in the first decade of

life were handicapped in developing verbal intelligence and memory capacity for verbal material, while the opposite results obtained for young children with right temporal epilepsy, who performed less efficiently on nonverbal tasks.

One group of studies attempted to predict differences on psychological tests accruing from right versus left temporal lobe damage, with the expectation that disorders in left temporal regions would result in lower verbal scores. Reitan (1955) confirmed these expectations using the Wechsler-Bellevue intelligence scale, although reporting himself unsure of the quality of his localizing procedures. DaCosta and Vaughn (1962), using various construction, visual, and verbal tests, found that patients with left temporal lesions performed poorly on verbal tests as compared to those with right-sided lesions, who performed poorly on tasks requiring visual-perceptual abilities. Lansdell (1962) reported similar results. Smith (1966), in assessing these particular studies, was less than impressed with the results, citing many flaws in methodology and concluding that the findings with respect to systematic differences in effect of left versus right hemispheric damage on verbal as opposed to nonverbal measures offered little consistency. A source of support for the view of the two hemispheres as subserving generally verbal (dominant or left hemisphere in the overwhelming majority of right-handed people) versus nonverbal (nondominant) functions comes from a recent study of the effects of unilateral and bilateral electroconvulsive therapy (ECT) which found that much less auditory verbal memory impairment resulted from unilateral nondominant ECT (Abrams, Fink, Rea, Dornbush, Feldstein, Volavka, and Roubicek, 1972). These results are paralleled by those of Samuels et al. (1972), who, in studying groups of patients with unilateral tissue

ablations found that left temporal subjects had greater impairment on auditory verbal memory tasks than did right temporal subjects with equivalent hippocampal damage. On the basis of his experiments, De Renzi (1967) concluded that the left hemisphere plays a major role whenever memory processes are aided by verbal or cognitive mechanisms.

An issue of significance for the present study stems from the fact that a number of researchers have found that right temporal lesions produce visual-discriminative defects (De Renzi, 1968; Fedio and Mirsky, 1969; Kimura, 1963; Milner, 1968). For this reason, recall of unfamiliar faces has been used as a measure of right temporal lobe dysfunction (De Renzi, Faglioni, and Spinnler, 1968); however, Kimura (1963, 1966) characterizes facial recognition as chiefly mnemonic in nature, and "verbally tagged" by the left hemisphere, citing evidence that recognition of faces may remain intact in persons with defective recognition for objects. Hopefully the present study will provide some clarification for this issue.

In summarizing the foregoing research, it appears that the most general (and safe) distinction that can be made between left and right hemispheric functions is between verbal and nonverbal skills, although the distinction has yet to be established absolutely. The possibility must also be considered that some supposedly nonverbal tasks may be mediated by verbal tagging, or implicit verbalization.

Memory Function in Epilepsy

As pointed out earlier, the fact of memory disruption in epileptics has long been noted, resulting in ever-increasing attention from researchers, many of whom have found epileptics a convenient population for the study of memory *per se*. Having reviewed some of the literature pertinent to localization and lateralization of memory functions, attention is now

turned toward that research concerned more specifically with memory functions in epileptics.

Turner (1907), in reviewing the literature available to that date, observed that the memory defect is manifested in epileptics even in cases of highly infrequent seizures. Deutsch (1953) studied populations of epileptics versus nonepileptics to determine whether the epileptics were significantly impaired on memory tasks as compared to normal subjects. Using epileptic subjects identified without regard to locus of the seizure activity, she did find memory performance in her epileptic population significantly impaired. These results have since been confirmed by other studies. Quadfasel and Pruyser (1955) compared a group of temporal lobe epileptics (identified via temporal lobe EEG distrubance and psychomotor seizure pattern) with a group of grand mal epileptics (identified through grand mal seizure activity and generalized, diffuse EEG abnormalities). Gross brain damage was ruled out in each subject. While the two groups were comparable in general intelligence, the temporal lobe epileptics were significantly less efficient in verbal retention and recall, although the two groups did not differ in nonverbal memory ability. The authors concluded that verbal and memory deficits are to be expected when abnormal temporal lobe EEG foci are present. A highly similar study (Mirsky et al., 1960) used groups of temporal lobe epileptics and those with diffuse-unlocalized abnormality, finding that the temporal lobe group did not perform nearly as well on memory tasks as would be expected from their general intellectual level, while the diffuse, unlocalized group displayed memory function at least equal to their general intellectual level. The authors also found that the nonfocal group scored significantly lower on

measures of attentiveness than did the focal-temporal group, leading them to conclude that attentiveness per se was not responsible for the impaired memory function of the temporal lobe group. Lorge (1964) found memory defects in 62.6% of a group of epileptics with abnormal temporal lobe EEG foci, and in only 29.4% of a group with more diffusely abnormal patterns. Blakemore et al. (1966) confirm the findings of greater memory disruption in temporal lobe epileptics, citing a trend in their data indicating that degree of impairment may be related to frequency of seizure activity. Kimura (1963, 1966), in testing patients with epileptogenic temporal foci, found that a focus in the left (dominant) temporal lobe resulted in impairment of auditory verbal perception and recall, whereas a right temporal group was significantly impaired in reproduction of unfamiliar visual stimuli. Stepien and Sierpinski (1960) reported no memory impairment with a group of focal lesion patients, concluding that bilateral damage was necessary to produce the memory disruption; however, a review of their methodology reveals that less than a third of their subjects had the focus in temporal areas. Scott, Moffett, Mathews and Ettlinger (1967) compared epileptic patients with normals on a series of nonverbal memory tasks in the auditory, tactual, and visual modalities, reporting no significant differences between the groups; however, the subject population was not confined to temporal lobe epileptics, nor were the temporal lobe subjects which were included well defined. Fedio and Mirsky (1969) compared three groups of epileptic children (age 6-14 years) with normals on a series of verbal and nonverbal memory tasks. They found patterns of deficit performance approximating those described for adults with similar disorders: those children with left temporal foci were impaired in memory capacity for verbal material, those with

right temporal foci were not impaired in verbal memory skills but performed less efficiently on nonverbal tasks, and those with non-temporal foci showed no significant verbal or nonverbal memory deficits when compared with normals.

Some authors have addressed the question of why the memory deficit exists in temporal lobe epileptic patients in the absence of any overt seizure activity. Many temporal lobe epileptics are identified by the presence of abnormal electrical activity in one or both hemispheres. Surwillo (1971) suggested that the abnormal electrical activity disturbs the synchronization of the two hemispheres, without which information loads are not efficiently processed, and memory traces are not formed. Kooi and Hovey (1957) concluded on the basis of experimentation that even relatively discrete electrical abnormality (which reflects underlying neurochemical activity) may interfere with the integrative circuits involved in memory processes. Morrell (1956) posited that the focal epileptogenic activity interferes with the temporary connections involved if learning is to take place. Blakemore et al. (1966) similarly linked the abnormal discharge activity and the difficulty in memory found in temporal lobe epileptics, but do feel that the frequency of seizure activity is a more important determinant in memory disruption than is the severity of the lesion itself. Scott et al. (1967) addressed the question of whether interictal (interseizure) EEG abnormalities impair learning and memory, failing to find evidence that interseizure electric abnormality is an important factor determining impairment on memory tasks. Evidence that activity caused by the lesion does impair memory performance comes from several authors (Horowitz, 1970; Milner, 1958; Piercy, 1964), who

reported improved performance on memory and learning tasks in patients who had epileptogenic foci surgically removed. A number of researchers have reported tissue damage in the form of incisural sclerosis, gliosis, or loss of neurons as underlying the abnormal electrical activity which characterizes the EEG records of epileptics (DeJong, 1973; Horowitz, 1970; Malamud, 1967; Penfield and Jasper, 1954); therefore, some degree of impairment in neural transmission might be expected in epileptics.

In summary, research to date has not only established the fact of memory disruption in epilepsy, but has in the process demonstrated that much is yet to be learned. Some of the more basic issues (amount and locus of damage necessary to produce memory problems, and determination of how best to examine for these problems) have been only slightly addressed, producing little consensus.

Statement of the Problem and Hypotheses

The point has been made that memory studies in epilepsy have not generally attempted to hold areas of involvement in the two hemispheres in constant relationship (Reitan, 1966). This view echoes Quadfasel and Pruyser (1955) who noted that strict and unique lateralization of EEG activity is rare, resulting in the use of questionable subjects in some studies. The need has also been cited for further clarification of the efficacy of psychological tests, especially those which tap memory function, in locating the focus of epileptogenic activity (DeJong, 1973; Dennerll, 1964; Lorge, 1964, Mirsky et al., 1960). The present study addressed these issues by utilizing a population of temporal lobe epileptic patients carefully matched for area of involvement, in whom memory functions were assessed by a number of verbal and nonverbal measures. It was expected that such measures could prove extremely useful in determination of the probable site of activity.

Based on current memory theories and previous research, certain results were expected from the present study. It was expected that subjects with left temporal lobe epileptic foci would perform more efficiently on nonverbal memory task than would right temporal lobe subjects, who would perform more efficiently on verbal memory tasks. Another expectation derived from Kimura (1963), who believed that a facial recognition task (FRT) is primarily mnemonic in nature, and verbally mediated by the dominant (left) hemisphere instead of the right. Contrary to its frequent usage as an indicator of right hemispheric dysfunction, it was expected that subjects suffering right temporal foci would perform significantly better on facial recognition tasks than would subjects with left temporal foci, given that verbal memory is an integral part of successful recall. A related, comparative expectation was that left temporal lobe subjects would perform significantly better on a visual reproduction task than would right temporal subjects, since the nature of that task did not permit time or provide stimuli for implicit verbalization, but rather required intact visual and spatial memory capacity.

In summary, the following hypotheses were offered as alternatives to the null hypothesis:

1. Subjects with left temporal lobe epileptic foci will perform more efficiently on nonverbal memory tasks than subjects with right temporal foci.
2. Subjects with right temporal lobe epileptic foci will perform more efficiently on verbal memory tasks than subjects with left temporal foci.
3. Subjects with right temporal lobe epileptic foci will perform significantly better on facial recognition tasks (FRT) than subjects with left temporal foci.

4. Subjects with left temporal lobe epileptic foci will perform significantly better on visual reproduction tasks than subjects with right temporal foci.

Specific expectations notwithstanding, the present study was intended to study memory functions in temporal lobe epileptics to shed some light in general on the questions of how such functions may help to characterize the disorder and assist in lateralizing and localizing the epileptic foci.

Chapter II

METHOD

Subjects

Subjects were twenty-eight right-handed male V.A. hospital patients who were identified as suffering unilateral temporal lobe epileptic foci. Fourteen of the subjects suffered left temporal foci, and fourteen, right temporal foci. They were identified through EEG (Electroencephalographic) recordings, pneumonencephalographs, brain scans, seizure history, and neurological examinations. Results of other neurological proceedings were used when available. Interpretation of data was performed by the chief of neurology service and residents in neurology in collaboration with neuropsychologists, all V.A. hospital staff, Gainesville Veterans Administration Hospital. Temporal lobe epileptic patients with any degree of bilateral involvement were rejected as subjects. Since strictly identified unilateral temporal lobe subjects comprise a highly restricted subgroup (approximately one in ten) of the population of temporal lobe epileptics, such subjects are rare. The group of twenty-eight used in the present study constituted one of the largest of such groups assembled to date for purposes of experimentation. The average age of the right temporal group was 45.4; that of the left temporal group, 50.2. In terms of education, the right temporal group averaged 11.2 years of school; the left temporal group, 10.8 years.

Since deficits in general intellectual functioning have been found

in temporal lobe epileptics (Drachman and Arbit, 1960; Lansdell, 1962; Needham, Bray, Wiser, and Beck, 1969; Pihl, 1968), intelligence of the subjects was measured using the Army General Classification Test (AGCT), a standardized measure of intelligence in use since World War II. The average AGCT standard score was 92.7 for the right temporal lobe group, and 92.6 for the left temporal group. While these scores are slightly lower than the average for the general population, they do not differ significantly between the two groups, nor from the V.A. hospital patient population as a whole.

Instruments

Each subject was administered the Wechsler Memory Scale, the Williams Scale for the Measurement of Memory, a facial recognition task, and the AGCT. A brief description of each instrument follows:

A. The Wechsler Memory Scale (Wechsler, 1945) consists of seven subtests and yields an MQ (memory quotient) analogous to an IQ. The seven subtests cover personal and current information, a measure of immediate orientation, a measure of "mental control" (repeating the alphabet, counting backward, etc.), logical memory, memory span for digits forward and backward, a visual reproduction task, and a paired associate learning task. Each of the seven subtests has been frequently used as independent measures separate from the scale as a whole.

B. The Williams Scale for the Measurement of Memory has not enjoyed the same wide usage as the Wechsler Memory Scale, having existed as an entity only a relatively short period. It consists of five subtests labeled Immediate Recall, Nonverbal Learning, Verbal Learning, Retention of Recent Events, and Memory for Past

Personal Events. Each of the subtests is scored independently, with weighted scores available for conversion from raw scores. Subtest scores are considered independently for purposes of assessing one's performance on the scale.

C. The Facial Recognition Task (FRT) consists of a set of photographs of twelve male faces which the subject studies for forty-five seconds. Following a ninety second delay interspersed with other tasks, the subject must then select the twelve from a group of twenty-four. His score is the number of correct choices in his first twelve responses.

D. The Army General Classification Task (AGCT) was chosen as the measure of intelligence. Its relatively short administration time (forty minutes) made it especially useful in this study, since the subjects were tested at length. It was originally developed during World War II to test military personnel, and offers well-established normative data and acceptable levels of correlation with other measures of general intelligence.

Procedure

Subjects were tested individually in a small, quiet room with only the subject and the examiner present. The examiner was unaware of the subject's classification as a right or left temporal case. The order of administration of the test instruments was held constant: The Wechsler Memory Scale, the Williams Memory Scale, the FRT, and finally, the AGCT. Instruments were administered according to the explicit instructions available with each. The entire sequence required approximately ninety minutes per subject.

Statistical Analysis

The data were subjected to a computerized multiple discriminant analysis (BMD07M, Stepwise Discriminant Analysis) which enters, at each step, one variable into a set of discriminating variables. Program output included group means and standard deviations, within groups covariance and correlation matrices, F statistics for the equality of means, and finally, discriminant functions and a classification matrix, indicating how well the variables used correctly characterized the subjects as right or left temporal cases. Variables entered into the program were the subject's age, years of education, FRT and AGCT scores, MQ, and subtest scores from the Williams and Wechsler memory batteries.

Chapter III

RESULTS

Hypotheses numbers one and two are related in that they are essentially mirror images each of the other. Support for one may provide support for the other in a reciprocal fashion.

Hypothesis 1: Subjects with left temporal lobe epileptic foci will perform more efficiently on nonverbal memory tasks than subjects with right temporal foci.

Hypothesis 2: Subjects with right temporal foci will perform more efficiently on verbal memory tasks than subjects with left temporal foci.

All of the respective group means for the relevant variables were in the expected direction (see Table 1). In terms of group means, right temporal cases performed better on verbal measures (memory passages, association learning, word learning, delayed recall, facial recognition) than left temporal cases, who performed better on nonverbal measures (visual reproduction, nonverbal learning). None of the magnitudes of differences in group means were sufficient to achieve significance at the univariate, single level of comparison; however, the stepwise discriminant analysis program used provided a multivariate view of various combinations of variables which did achieve predictive significance (see Table 2). An inspection of the F values for the variables in combination reveals that the groups performed as expected. Table 2 indicates the six most powerful predictors of left versus right cases and their combination F values. It may be seen that with the addition of each variable the U-statistic

Table I

Respective Group Means for Each Variable

Variable	Right Group Means	Standard Deviation	Left Group Means	Standard Deviation
Age	45.36	14.39	50.21	13.31
Years of Education	11.43	1.22	10.50	2.65
Memory Passages	8.79	3.60	8.00	3.09
Digit Span	10.14	2.18	10.86	2.45
Visual Reproduction	6.14	3.78	7.36	2.47
Association Learning	13.14	4.22	10.86	3.13
Memory Quotient	94.14	15.02	96.29	15.00
FRT	8.71	1.38	8.21	1.53
Word Learning	3.79	2.78	2.14	1.75
Delayed Recall	6.14	2.32	4.79	2.52
Nonverbal Learning	4.71	2.16	5.50	3.06
AGCT Score	92.71	22.17	92.64	30.12

Table 2

Optimum Sets of Predictors for Right vs. Left Cases

Variables in Set	df	F Value	Probability	U-Statistic
Memory Quotient Word Learning	25	6.35	$p < .05$	.6632
Memory Quotient Word Learning Years of Education	24	5.62	$p < .05$	.5872
Memory Quotient Word Learning Years of Education Nonverbal Learning	23	5.81	$p < .05$	.4977
Memory Quotient Word Learning Years of Education Nonverbal Learning Association Learning	22	5.42	$p < .05$	.4480
Memory Quotient Word Learning Years of Education Nonverbal Learning Associate Learning Age of Subject	21	5.15	$p < .05$	.4047

$p < .05$ $F > 4.22$ (for d.f. = 21)

(a measure of uncertainty, in this case the probability of inclusion into the wrong group) decreased. Addition of the remaining variables continued to reduce the probability of misclassification, although by only slight degrees. With the data input provided, the program accurately identified ten of the fourteen right temporal cases and twelve of the fourteen left temporal cases. These results provided qualified support for hypotheses numbers one and two, qualified in the sense that not all of the verbal and nonverbal measures differentiated powerfully enough to aid significantly in the classification of cases.

Hypothesis 3: Subjects with right temporal epileptic foci will perform significantly better on a facial recognition task (FRT) than subjects with left temporal foci.

Although the respective means were in the expected direction (Right Group mean = 8.71, Left Group mean = 8.21), the results did not achieve significance and were discarded in favor of the null hypothesis.

Hypothesis 4: Subjects with left temporal lobe foci will perform significantly better on a visual reproduction task than subjects with right temporal foci.

Here, too, the means were in the expected direction (Right Group mean = 6.14, Left Group mean = 7.36) but failed to reach significance. The alternative was discarded in favor of the null hypothesis.

In summary, hypotheses numbers one and two received qualified support, while hypotheses numbers three and four received none, and were discarded in favor of the null hypothesis.

Chapter IV

DISCUSSION

The fact that memory data (along with readily obtainable personal data) can result in an impressively accurate (twenty-two of twenty-eight cases correctly identified for a 79% accuracy rate) classification of temporal lobe epileptic cases is most encouraging, more so when it is considered that the subjects used were without exception highly functional people free of any gross cerebral dysfunction. Differences in performance among such subjects are likely to be subtle, and not easily detected through cursory neurological or psychological evaluation, especially in the case of dormant or highly infrequent seizure activity. While experimenter demand effect might be considered as a contributing factor, the data in this study were collected by an extremely naive examiner trained only to administer the instruments used, and entirely unaware of the purposes of the study or the classification of the subjects into the right or left group. Given such data, single variables and univariate analysis are not equal to the task of detection. In a recent study (Goldstein and Shelly, 1973) two groups of brain damaged subjects (right versus left hemisphere cases) were administered a number of neurological and neuropsychological tests. The data were subjected to three forms of analysis: univariate analysis, factor analysis, and discriminant (multivariate) analysis. The discriminant analysis method correctly identified substantially more cases than the other methods. Since memory function is such a highly complex phenomenon, in any single individual the dimension of dysfunction identified by any single variable might not

be present. Certainly in the present study multivariate analysis proved more effective than the univariate output (F value for each single variable) given as an initial step of the discriminant analysis.

One question which might be addressed is why the variables used in this study were more effective in detection of left than of right temporal cases (86% versus 71% accuracy of classification). Examination of the neurological data used to classify each case as right or left revealed no systematic differences in the amount and kinds of data available and used in establishing the groups as the independent variables; therefore, there is no presumptive reason to assume that one group was more soundly established than the other. Perhaps a more fruitful line of reasoning concerns the nature of most of the variables used. The large majority were essentially verbal in nature, so that any dysfunction in left temporal areas was much more likely to be detected. Clearly there is a need for more and better nonverbal memory measures, since such measures might dramatically increase the discriminative value of a battery of memory measures. Evidence that certain of the supposed nonverbal memory measures used as variables in the present study are of dubious value might be seen from an examination of hypotheses numbers three and four. Although neither of the hypotheses as stated was supported by the results, it is nevertheless instructive to review them. Hypothesis number three stated the expectation that right temporal subjects would perform significantly better on a facial recognition task than left temporal subjects would. This was posited after Kimura (1963), who believed that facial recognition tapped verbal, mnemonic processes instead of nonverbal processes. Nevertheless, facial recognition is yet used as an indicator of nonverbal memory dysfunction. While the difference did not reach the level of significance, right temporal

subjects did perform better than left temporal subjects, casting some doubt on its usefulness as an indicator of nonverbal memory function. Hypothesis number four stated that left temporal subjects would perform significantly better on a visual reproduction task than right temporal cases would. Again, although the results were in the expected direction, they failed to achieve significance. This is disappointing, since the visual reproduction task appears to fit the criterion for a nonverbal memory task. The figures used supposedly have low verbal stimulus value, and the length of time elapsed between presentation of the figures and reproduction of them is hardly sufficient, it might be supposed, to permit verbal rehearsal. In this respect it is encouraging to note that the nonverbal learning subtest of the Williams Scale did contribute substantially to the discriminant analysis, although not reaching significance when considered as a single variable. The fact that visual reproduction and the nonverbal learning subtest of the Williams Scale did not achieve significance when considered singly does not rule them out as useful measures, even when used alone with subjects whose cerebral dysfunction is much less subtle than that of the subjects used in the present study; however, the results of the facial recognition task (FRT) cast strong doubt on its absolute utility, and indicate a strong need for followup study with a large number of cases.

Some other, fairly interesting, results were revealed by the within groups correlation matrix (see Table 3). Age was negatively correlated with every other variable, although significance was achieved only between age and visual reproduction and age and delayed recall. It might be noted that although both groups were integrated, the race variable did not achieve a significant intercorrelation with any other variable, nor did it contribute to the discriminant analysis.

Table 3

Within Groups Correlation Matrix

Variables	Age	Education	Memory Passages	Digit Span	Visual Reproduct'n	Association Learning	Memory Quotient	FRT	Word Learning	Delayed Recall	Non-verbal Learng	AGCT	Race
Age	1.00												
Education	-0.30	1.00											
Memory Passages	-0.28	0.40	1.00										
Digit Span	-0.48	0.37	0.32	1.00									
Visual Reproduct'n	-0.76	0.30	0.34	0.45	1.00								
Association Learning	-0.57	0.18	0.31	0.59	0.61	1.00							
Memory Quotient	-0.27	0.42	0.74	0.69	0.46	0.69	1.00						
FRT	-0.54	0.42	0.34	0.36	0.71	0.46	0.45	1.00					
Word Learning	-0.47	0.23	0.71	0.63	0.40	0.64	0.80	0.38	1.00				
Delayed Recall	-0.75	0.38	0.42	0.43	0.70	0.73	0.48	0.55	0.54	1.00			
Nonverbal Learning	-0.55	0.43	0.35	0.30	0.52	0.24	0.30	0.44	0.38	0.46	1.00		
AGCT	-0.15	0.22	0.52	0.37	0.36	0.35	0.62	0.39	0.54	0.21	0.40	1.00	
Race	0.15	0.11	0.25	-0.09	-0.08	-0.19	0.03	-0.13	-0.00	-0.18	0.14	0.20	1.00

$p < .05$ "r" $> .706$

Perhaps most noteworthy in these results are findings that a series of memory tasks can serve as highly accurate predictors even in cases of very subtle levels of dysfunction. Continuing to add subjects to the existing data pool might prove useful, or perhaps more so, to cross-validate these existing results with data from new subjects. Re-analysis of the data after dropping out nondiscriminating variables (thereby reducing "noise" in the analysis) offers one possibility for identifying a most highly discriminating set of variables, as does identifying and adding new, perhaps more sensitive memory tasks to the set of variables currently used.

Developing new memory tasks and discovering how best to use existing ones in characterizing temporal lobe epilepsy (and other cerebral disorders as well) offer a great deal of challenge to the interested researcher. Results of the present study might prove immediately useful to the diagnostician who must characterize such cases. For this reason, and to permit comparisons between this and other studies, the weights assigned to each variable by the discriminant function program are listed (see Appendix A).

APPENDIX A

Program-Assigned Variable Weights

Variable	Right	Left
Age	1.540	1.444
Years of Education	0.716	-0.209
Memory Passages	0.698	0.309
Digit Span	4.149	4.228
Visual Reproduction	0.321	0.607
Association Learning	1.827	0.874
Memory Quotient	-0.469	-0.070
FRT	6.673	6.002
Word Learning	-0.949	-2.249
Delayed Recall	2.831	3.023
Nonverbal Learning	1.099	1.428
AGCT	-0.125	-0.136
Constant	-100.630	-102.589

REFERENCES

Abrams, R., Fink, M., Dornbush, R., Feldstein, S., Volavka, J., and Roubicek, J. Unilateral and bilateral electroconvulsive therapy. Archives of General Psychiatry, 1972, 27, 88-91.

Blakemore, C. B., Ettlinger, G., Falconer, M. A. Cognitive abilities in relation to frequency of seizures and neuropathology of the temporal lobes in man. Journal of Neurology, Neurosurgery, and Psychiatry, 1966, 29, 268-272.

Blakemore, C. B., and Falconer, M. A. Long-term effects of anterior temporal lobectomy on certain cognitive functions. Journal of Neurology, Neurosurgery, and Psychiatry, 1962, 25, 154-158.

DaCosta, L. and Vaughn, H. Performance of patients with lateralized cerebral disorders. Journal of Nervous and Mental Disorders, 1962, 134, 162-168.

DeJong, R. N. The hippocampus and its role in memory. Journal of the Neurological Sciences, 1973, 19, 73-83.

Dennerll, R. D. Cognitive deficits and lateral brain dysfunction in temporal lobe epilepsy. Epilepsia, 1964, 5, 177-191.

De Renzi, E. Nonverbal memory and hemispheric side of lesion. Neuropsychologia, 1968, 6, 181-189.

De Renzi, E. and Faglioni, P. Intelligence and vigilance tests in brain damaged patients. Cortex, 1965, 1, 410-433.

De Renzi, E., Faglioni, P., and Spinnler, H. The performance of patients with unilateral brain damage on face recognition tasks. Cortex, 1968, Vol. 4, No. 1, p. 17.

Deutsch, D. P. Differences among epileptics and between epileptics and nonepileptics in terms of some memory and learning variables. Archives of Neurology and Psychiatry, 1953, 70, 474-482.

Dimsdale, H., Logue, V., and Piercy, M. A case of persisting impairment of recent memory following right temporal lobectomy. Neuropsychologia, 1963, 1, 287-298.

Drachman, D. and Arvit, J. Memory and the hippocampal complex. Archives of Neurology, 1966, 15, 62-61.

Fedio, P. and Mirsky, A. Selective intellectual deficits in children with temporal lobe or centrencephalic epilepsy. Neuropsychologia, 1969, 7, 287-300.

Goldstein, Gerald and Shelly, Carolyn H. Univariate vs. multivariate analysis in neuropsychological test assessment of lateralized brain damage. Cortex, 1973, 36, 204-215.

Gowers, W. R. Epilepsy. London: J. & A. Churchill, Ltd., 1881.

Horowitz, M. J. Visual imagery and cognitive organization. American Journal of Psychiatry, 1970, 123, 938-946.

Kimura, D. Right temporal lobe damage: Perception of unfamiliar stimuli after damage. Archives of Neurology, 1963, 8, 264-271.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kooi, K. and Hovey, H. B. Alterations in mental function and paroxysmal cerebral activity. Archives of Neurology and Psychiatry, 1957, 78, 264-271.

Kolodny, A. Symptomatology of tumor of the frontal lobe. Archives of Neurology and Psychiatry, 1929, 21, 1107-1127.

Lansdell, H. Laterality of verbal intelligence in the brain. Science, 1962, 135, 922-923.

Lombroso, C. The Man of Genius. New York: Columbia, 1891

Lorge , M. Epilepsic and lebensschicksal. Psychiatric Neurology (Basel), 1964, 147, 360. Cited by Ernst A. Rodin, The Prognosis of Patients with Epilepsy. Springfield, Ill.: Charles C. Thomas, 1968.

MacKay, R. P. Towards a neurology of behavior. Neurology, 1955, 4, 894-901.

Malamud, N. Psychiatric disorders with intracranial tumors of limbic system. Archives of Neurology, 1967, 17, 113-123.

McFie, J. and Piercy, M. F. Intellectual impairment with localized cerebral lesions. Brain, 1952, 75, 292-311.

Milner, B. Psychological defects produced by temporal lobe excision. Proceedings of the Association for Research in Nervous and Mental Disorders, 1958, 36, 244-257.

Milner, B. Brain mechanisms suggested by studies of the temporal lobes, In Brain Mechanisms Underlying Speech and Language, ed. by F. L. Darley, Grune, & Stratton. New York: Academic Press, 1967.

Milner, B. Visual recognition and recall after right temporal lobe excision in man. Neuropsychologia, 1968, 6, 191-210.

Milner, B. Memory and the medial temporal regions of the brain. In K. H. Pribram and D. E. Broadbent (Eds.) The Biology of Memory. New York: Academic Press, 1970.

Milner, B. and Teuber, H. Alteration of perception and memory in man. In L. Weiskrantz (Ed.) Analysis of Behavioral Change. New York: Harper & Row, 1968.

Mirsky, A. F., Primac, D. W., Marsan, C., Rosvold, H. E. and Stevens, J. R. A comparison of the psychological test performance of patients with focal and nonfocal epilepsy. Experimental Neurology, 1960, 9, 463-469.

Morrell, F. Interseizure disturbances in focal epilepsy. Neurology, 1956, 6, 327-334.

Needham, W. E., Bray, P. F., Wiser, W., and Beck, E. C. Intelligence and EEG studies in families with idiopathic epilepsy. Journal of the American Medical Association, 1969, 207, 1947-1501.

Penfield, W. and Jasper, H. Epilepsy and the Functional Anatomy of the Human Brain. Boston: Little, Brown, 1954.

Penfield, W. and Milner, B. Memory deficits produced by bilateral lesions in the hippocampal zone. Archives of Neurology and Psychiatry, 1958, 79, 475-497.

Piercy, M. The effects of cerebral lesions on intellectual functions; A review of current research trends. British Journal of Psychiatry, 1964, 110, 310-352.

Pihl, R. O. The degree of the verbal-performance discrepancy on the WISC and WAIS and severity of EEG abnormality in epileptics. Journal of Clinical Psychology, 1968, 24, 419-20.

Quadfasel, A. F. and Pruyser, P. W. Cognitive deficit in patients with psychomotor epilepsy. Epilepsia, 1955, 4, 80-90.

Reitan, R. M. Certain differential effects of right cerebral lesions in human adults. Journal of Comparative and Physiological Psychology, 1955, 48, 474-477.

Reitan, R. M. Problems and prospects in studying the psychological correlates or brain lesions. Cortex, 1966, 2, 127-154.

Samuels, I., Butters, N. and Fedio, P. Short-term memory disorders following temporal lobe removals in humans. Cortex, 1972, 3, 283-298.

Scott, D. F., Moffett, A., Mathews, A. and Ettlinger, G. The effect of epileptic discharges on learning and memory in patients. Epilepsia, 1967, 8, 188-194.

Scoville, W. B. The limbic lobe in man. *Journal of Neurosurgery*, 1954, *11*, 64.

Scoville, W. B. and Milner, B. Loss of recent memory after bilateral hippocampal lesions. *Journal of Neurology*, London, 1957, *20*, 11-21.

Serafetinides, E. A. Memory for words and memory for numbers. *Journal of Learning Disabilities*, 1969, *2*, 142-143.

Serafetinides, E. A. and Falconer, M. A. Some observations on memory impairment after temporal lobectomy for epilepsy. *Journal of Neurology, Neurosurgery, and Psychiatry*. 1962, *25*, 251-255.

Smith, A. Certain hypothesized hemispheric differences in language and visual functions in human adults. *Cortex*, 1966, *2*, 109-126.

Stepien, L. and Sierpinski, S. The effect of focal lesions of the brain upon auditory and visual recent memory in man. *Journal of Neurology, Neurosurgery, and Psychiatry*, 1960, *23*, 334-340.

Surwillo, W. W. Interhemispheric EEG differences in relation to short-term memory. *Journal of Clinical Neurology*, 1971, 93-95.

Temkin, O. *The Falling Sickness*. Boston: Johns Hopkins Press, 1945.

Turner, W. A. *Epilepsy*. London: Macmillan, 1907.

Victor, M. Observations on the amnestic syndrome in man and its anatomical basis. In M. Brazier (Ed.) *Brain Function II: RNA and Brain Function, Memory and Learning*. Los Angeles: University of California Press, 1964.

Wechsler, D. A. A standardized memory scale for clinical use. *Journal of Psychology*, 1945, *19*, 87-95.

Williams, M. The measurement of memory in clinical practice. *British Journal of Social and Clinical Psychology*, 1968, *7*, 19-34.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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